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ABSTRACT

This paper explores the preliminary results of an ongoing 3-year study of cognitive function and cognitive education among hearing-impaired persons (n=200) and considers these results in the context of previous studies. Cognitive task performance among the deaf was below average for the verbal and sequential skills associated with the left hemisphere, but more importantly, performance was above average for visual and spatial skills associated with the right hemisphere. Reading and mathematics achievement directly correlated with this cognitive profile, especially with verbosequential performance. (Author/PB)

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SPECIALIZED COGNITIVE FUNCTION AMONG DEAF INDIVIDUALS: IMPLICATIONS FOR INSTRUCTION[1]

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Abstract

This paper explores the preliminary results of an on-going 3-year study of cognitive function and cognitive education among hearing-impaired persons and considers these results in the context of previous studies (Craig & Gordon, 1988; McKee, 1987). In the earlier studies the cognitive profile of deaf individuals was found to differ significantly from that of normally-hearing persons. Cognitive task performance was below average, as might be expected, for the verbal and sequential skills associated with the left hemisphere, but more importantly, performance was above average for the visual and spatial skills associated with the right hemisphere. In addition, reading and mathematics achievement directly correlated with this cognitive profile, especially with verbosequential performance. In potentially related investigations (Craig, 1987; Martin & Jonas, 1986), the systematic implementation of a thinking skills program, Feuerstein's Instrumental Enrichment (FIE), has been found significantly to improve reading and mathematics achievement among deaf students. FIE is a metacognitive program which includes a selective focus on several of the visuospatial and verbosequential features associated with specialized cognitive function. Consideration of the FIE results and of their potential interaction with our findings on brain function formed the basis for the current investigation. Our plan is: (1) to evaluate 200 hearing-impaired subjects with the Cognitive Laterality Battery (CLB) (Gordon, 1986) and (2) to analyze the FIE program as implemented with 48 students from a post-secondary transitional program. The project extends the subject pool of hearing-impaired individuals evaluated with the CLB, specifically including students and adults with differing degrees of hearing loss (from 55-80 dB and > 90dB) and with varying ages of onset, so that the influence of these variables can be assessed. The project also seeks to determine more fully the relationship between cognitive profile and academic achievement among deaf students, and to assess the potential impact of different cognitively-based intervention within FIE on such achievement. Students are divided into two treatment groups, one providing FIE training using instruments which focus on visuospatial skills, and the other using instruments which emphasize the verbo-sequential. Within each training group, students

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are further divided according to whether their cognitive profiles favor verbosequential or visuospatial abilities. In this way we can determine, for example, whether a match between the training technique and the student's cognitive profile will facilitate or impede achievement. The first-year results, based on CLB evaluation of 65 hearing-impaired adults and of FIE intervention with 16 hearing-impaired students, will be presented at the Second International Symposium on Cognition, Education, and Deafness in July, 1989.

Introduction

The potential relationship of specialized cognitive function and laterality to profound, congenital hearing impairment and to academic achievement and development of thinking skills, has only recently been the subject of investigation -- although individual factors such as reading achievement and cognitive skill development have long been the subject of analysis and debate. Thipaper discusses and synthesizes related findings both from recently reported investigations of cognitive function (Craig & Gordon, 1988; McKee, 1987) and cognitive skill development (Craig, 1987) and from the first year of an ongoing 3-year study of cognitive function and achievement in deaf persons.

The purpose of this project is both theoretical and practical. The theoretical goal is to extend our previous results in determining whether the pattern of performance of specialized brain functions -- the cognitive profile -- differs between individuals who have normal vs. impaired hearing. The practical goal is to determine whether the cognitive profile of hearing-impaired students can help to predict which training materials will most greatly facilitate their academic achievement. The objectives, then, are four-fold: (1) to further explore, with a cohort of congenitally and profoundly deaf persons: (a) the relative peformance of cognitive functions associated with the left and right hemispheres and (b) the laterality of brain function; (2) to determine whether there exists a "critical period" for development of brain organization and/or a "critical degree of deficit" relating to differing ages of onset and differingdegrees of hearing loss; (3) to explore the relationship between cognitive profile and academic

achievement; and (4) to determine whether success in a training program in thinking skills (Feuerstein's Instrumental Enrichment) can be attributed to the nature of training material that favors specialized brain function -- specifically, whether a match or mismatch of materials to cognitive profile in the students will be most effective for improvement in academic achievement. [See attached "Glossary" for further explanation of the terminology relating to hemisphericity as used in this report.]

Rationale and Review of Previous Studies

The main theoretical hypothesis underlying this series of studies is that congenital loss of auditory experience alters the cerebral development and normal lateralization of specific cognitive tasks associated with brain functions, particularly of neurosystems associated with the left cerebral hemisphere. It is further hypothesized that these developmental differences may well be a critical factor influencing the academic achievement of persons with profound and congenital hearing impairment and, by extension, that intervention techniques which take into consideration the cognitive profile of each deaf student may produce a better outcome in academic achievement.

Underlying these hypotheses are two basic and potentially interacting factors: (1) the identification of the left hemisphere as an analytic, serial, and time-dependent processor, uniquely specialized for speech, writing, and other language skills (Bradshaw & Nettleton, 1983), and (2) the observation that children whose hearing is significantly impaired, regardless of preferred communication mode, miss a major portion of the highly sequential and temporal input that is conveyed auditorily. It is also reasonable to suppose that continued deprivation of serial stimuli may further reduce development of these processes in the left hemisphere, whereas increased reliance on visual sources, which are inherently less sequential than the

auditory, may potentiate right-hemisphere development. Although children who are profoundly hearing impaired have access in varying degrees to some verbal and sequential input (through lipreading, readin, and/or Sign), they have very limited access to the major source of such input from birth onward -- the daily and ubiquitous auditory stimulation of people talking. In the process of compensating for this lack, they may overly rely on the right cerebral hemisphere and neglect the left, even for language tasks.

A similar explanation has been suggested both for dyslexia and for reduced academic achievement among normally hearing children (Gordon, 1980; Gordon, 1984; Harness, Epstein & Gordon,1984; Gordon, 1988). Almost all the subjects in these studies were found to have a large cognitive asymmetry favoring the right hemisphere, with the cognitive profile indicating not only a below average performance on the verbosequential skills associated with the left hemisphere, but an above average performance on the visuospatial skills of the right.

Cognitive studies of hearing-impaired persons began with the assessment of IQ and digit-span memory by Pintner and colleagues (1917, 1920, 1927, 1941), but only recently have investigators begun to focus on the potential relationship between impaired hearing and the specialized cognitive functions associated with the left and right hemispheres. In experimental studies of visual field preference using tachistoscopic presentation to the left and right visual hemifields, deaf subjects have shown a reduced asymmetry for English-language stimuli (e.g., Kelly and Tomlinson-Keasey, 1977), inconsistent or negligible asymmetries for static sign stimuli (e.g., McKeever et al., 1976) and no asymmetry for moving sign stimuli (e.g., Poizner et al., 1979). In contrast, normally hearing subjects consistently demonstrate a strong right visual field (left hemisphere) advantage for verbal material and a left visual field advantage for non-verbal material. In clinical studies of hearing-impaired patients with left-hemisphere brain damage

(e.g., Poizner et al., 1984), expressive and receptive sign language abilities have been found to be severely impaired, just as spoken language skills are reduced by left hemisphere damage in normally hearing persons.

The above studies have essentially concentrated on the localization of cognitive functions in either the right or left hemisphere, not upon the degree of development of specialized brain functions, regardless of their location. The studies described below are focused on the developmental issue, and therefore upon the relative performance of the cognitive tasks usually associated with one or the other hemisphere.

Studies Leading to Current Project

Coonitive Evaluation

The ability to assess relative performance on specialized brain functions has been facilitated in the past decade by the development of a battery of tests, the Cognitive Laterality Battery (CLB) (Gordon, 1986), specifically designed to measure the verbosequential and visuospatial functions attributed respectively to the left and right cognitive hemispheres. The tests were derived from converging evidence from studies on unilateral lesion patients and normal subjects; they were validated for hemispheric specialization by being administered to each hemisphere of patients with complete commisurotomy (Gordon and Zaidel, 1982). Repeated validation of the factor structure has been demonstrated in several populations, each showing two orthogonal factors respectively consisting of tests of visuospatial and verbosequential function. Most important for this study, the same two factors have been obtained from a deaf sample with an adapted version of the CLB.

Two studies using the adapted CLB already have been conducted with samples of hearing-impaired subjects. The first study (Craig and Gordon, 1988) was specifically designed to

evaluate the specialized cognitive performance of 62 adolescents in a school for deaf children and to explore the linkage between cognitive profile and reading achievement. Fifty-five (55) of the subjects were profoundly deaf (BEA > 90dB); the other 7 had moderate-to-severe loss (BEA = 73-89 dB). More than 75% (n = 47) were deaf from birth, 13 became deaf before 2 years, the other 2 by age 6.

The cognitive profile for the entire sample indicated better performance on the visuospatial tasks, compared to the verbosequential, by nearly 3/4 of a standard deviation. This result was significantly different from the expected mean of zero ($t = 5.29$; $p < .001$).

In this study, reading performance on the Stanford Achievement Test (SAT) proved to be significantly correlated with cognitive profile ($r = -.330$; $p < .01$), as to a lesser extent, did mathematics concepts on the SAT and speech production scores on the Goldman-Fristoe Test of Articulation. In particular, verbosequential skills -- both verbal fluency and serial tasks -- were highly correlated with academic achievement, whereas the visuospatial skills evidenced only weak relationships to academic performance. One other factor in particular which addresses the developmental issue is the relation of cognitive-test performance to age-of-onset; here prenatally (hereditary) hearing-impaired group performed significantly better than the postnatal group (most of whom were nevertheless prelingually deaf) on the visuospatial tests associated with the right hemisphere.

A second study with the CLB was performed with hearing-impaired university students (McKee, 1987). In confirmation of the first study, the subjects performed significantly below average on the composite verbosequential tests and significantly above average on the composite visuospatial tests. In order to control for language environment, a special contrast group was included, made up of hearing subjects whose parents were deaf and who had

consistently used sign language in the home. This group's performance was in distinguishable from the hearing norm, suggesting that deafness per se, and not mode of communication or early language environment, may be responsible for differential performance on brain-related skills. Again, results differed between age-of-onset groups, with lower verbosequential performance recorded for subjects with congenital onset of profound deafness than for those with later onset or less profound loss of hearing.

Cognitive Training and Academic Achievement

In recent years, a new intervention program, Feuerstein's Instrumental Enrichment (FIE) (Feuerstein, 1980) has been used with deaf students in some schools and classes for the deaf, with success in improving both cognitive skills and academic performance (Craig, 1987; Martin and Jonas, 1986). FIE is a systematic metacognitive program for improving thinking and academic performance through a comprehensive and targeted set of learning materials, a theoretically cohesive instructional plan, and an extensive and interactive teacher-training process. Based on a construct of "cognitive modifiability", it is designed to transform "retarded performers" into active, independent thinkers, through a focused attack on cognitive deficiencies. FIE was originally designed to serve culturally-disadvantaged students, but it has since been found effective with several different groups (Savell et al., 1986). The 14 learning instruments in FIE are a series of challenging problem-solving tasks and exercises in specific areas of cognitive development such as: projecting relationships, orientation in space, classification, temporal relations, hierarchical relations, and transitive relations. The instruments are intentionally taught separately from specific subject matter so that a clear and unambiguous focus can be directed on the thinking itself. The content is then related back to academic concepts with interactive "bridging" activities by the teacher. The science teacher, for example,

who is discussing the FIE instrument "Analytic Perception," will relate the whole/part concepts to analysis of the solar system, to geologic time spans, aerobic respiration, solvents and solutions, or atomic structure. The reading teacher may use the same instrument to bridge to an analysis of short-story plot, a character in the story, or the relation between phonemes and overall word pronunciation.

Positive results from FIE intervention have been reported from its implementation at the Western Pennsylvania School for the Deaf (WPSD) (Craig, 1987) and at the Model Secondary School for the Deaf (MSSD) (Martin and Jonas, 1986). In these studies, both conducted over a two-year period, secondary-level students in the experimental groups were provided with systematic instruction in cognitive skills for at least two class periods per week, using FIE, while the control groups received the regular academic instruction (e.g., reading, language, mathematics) usually scheduled at that time. The WPSD study included 20 experimental and 20 control subjects; the MSSD study 41 experimental and 41 controls.

Results from the WPSD study (Craig, 1987) showed that the students trained in FIE made significantly higher gains than the control students on the Reading Comprehension subtest of the SAT. Over the 2 years, the FIE-trained group made a scaled score gain of 14.7, compared to the non-FIE group gain of 9.5 ($t = 3.83$; $p < .01$). For the FIE group, this represents a Grade Equivalent (GE) gain of 1.68 (or 0.84 per year), almost triple the average yearly gain in SAT Reading Comprehension reported for deaf students nationwide (Trybus & Karchmer, 1977). The WPSD experimental group also gained significantly higher scores on the Minnesota Paper Form Board (a measure of spatial problem-solving) than did the controls ($t = 3.23$; $p < .05$). Both FIE and non-FIE groups made significant gains in Math Computation on the SAT

and on the Raven's Standard Progressive Matrices, although group differences here were not significant.

Results from MSSD (Martin and Jonas, 1986) closely parallel those from WPSD. The FIE-trained students gained a GE of 1.6 on the SAT Reading Comprehension subtest over the 2-year period, compared with a gain of only half as much (0.8) for the controls ($p < .05$). Similar significant improvements were seen for SAT Math Computation and Math Concepts. In addition, the MSSD FIE-trained students showed a gain of 8.1 percentile points over 2 years for the Raven's Standard Progressive Matrices, compared to a gain of only 1.8 in the controls ($p < .01$). Additional results from teacher rating scales at both MSSD and WPSD showed that the FIE students gained in classroom behavior and work habits observed during the training period. Thus, in both schools, the FIE program appears to be causally related to cognitive and academic gains among deaf students.

During this same period of achievement gain in both settings, it was not clear whether the students' cognitive profiles had changed at all. This factor is assessed in the current study. If the profile does not change, it would suggest that the cognitive training method is specific for improving general cognitive and academic skills but does not work by the functional specialization of one hemisphere or the other. What we do not know, and hope to determine from this new study, is whether a subject's cognitive profile is important for successful cognitive training. For example: Do subjects with profiles favoring visuospatial skills benefit more from a program that also favors visuospatial functions or from a program that emphasizes the verbosequential? In other words, does congruency between cognitive profile and training technique produce greater educational gains than training techniques that may compensate for

weaknesses in the profile? Much has een speculated about these two possibilities, but no study has yet commpared them side-by-side.

Method

The implementation of the current study involves two major components, corresponding to the theoretical and practical goals discussed earlier -- (1) Cognitive Evaluation; and (2) Cognitive Training -- each conducted throughout the 3-year period. These are diagrammed in Table I and discussed separately below.

Evaluation Comoonent:

Subjects. The hearing-impaired subjects for the cognitive evaluation component are being recruited from a large pool of both students and adults, including those from a school and from classes for the hearing-impaired, a transitional post-secondary program, the mailing list of a local organization serving hearing-impaired adults, and clients from the Department of Otolaryngology at a local hospital. Approximately 200 subjects will be recruited over the 3 years, to be divided evenly into 4 cells in a 2 x 2 matrix, and grouped according to age of onset and severity factors, as shown in Table 1. The Age-of-Onset groups, clearly non-overlapping, include subjects whose hearing loss is: (1) congenital and (2) post-lingual (onset at 36 months or later). The Degree-of-Hearing-Loss groups, also non-overlapping, are those whose loss is: (1) profound (>90 dB) and (2) moderate to moderately-severe (55-80 dB). Subjects are limited to those between the ages of 15 and 30 years and with Performance IQs above 80. Other variables are being assessed, including handedness, gender, preferred and secondary modes of communication, hearing status of parents, and sign proficiency; but subjects are not excluded or grouped according to these factors.

Test Instruments. The tests being administered include: (1) the 4 verbosequential tests of sequencing and word fluency from the CLB -- Serial Pictures, Serial Numbers, Word Production: Letters, Word Production: Categories; (2) an additional non-verbal test of sequencing, "Serial Circles" (Gordon, 1980); (3) an additional non-English language test of fluency, "Sign Production: Letters"; (4) the 4 visuospatial tests from the CLB --Localization, Orientation, Form Completion, Touching Blocks; (5) tests of hand dominance (Briggs and Nebes, 1975); (6) tests of hand performance, which have proved to be significant predictors of laterality (Shankweiler and Studdert-Kennedy, 1975) -- the Tracing, Tapping and Precision Dotting subtests of the Tests of Mechanical Abilitv (MacQuarrie, 1953); and (7) the Reading Comprehension, Mathematics Computation, and Mathematics Concepts subtests of the Stanford Achievement Test (SAT) (Gardner et al., 1982).

Procedure. Subjects are tested by a research assistant who is trained and fluent in Sign and experienced with deaf persons at various levels of performance. The performance tests of the CLB, including signed instructions, are presented on videotape and 35mm slides. When necessary, instructions will be clarified by the examiner, with additional demonstration and explanation. Subjects in the categories of less hearing loss and post-lingual onset, who may also be less proficient in Sign, are given instructions orally if this is their preferred mode. Comprehension of the tests themselves is not dependent upon any language system, with the exception of the "Sign Production: Letters", which is omitted for persons not familiar with Sign.

Table 1. Matrices for Evaluation and Training Components in 3-Year Study of Specialized Cognitive Function

EVALUATION COMPONENT: Distribution of Subjects

	Degree of Hearing Loss	
Age of Onset	55-80 dB	> 90 dB
Congenital	48 subjects	48 subjects
Post Lingual (36 months)	48 subjects	48 subjects

TRAINING COMPONENT: Distribution of Subjects

	Focus of FIE* Instruments	
Cognitive Profile of Subjects	Visuospatial	Verbosequential
Visuospatial > Verbosequential	12	12
Verbosequential > Visuospatial	12	12

*Feuerstein's Instrumental Enrichment (Feuerstein, 1980)

Training Components

Subjects. The subjects for the training component will be selected from a post-secondary transitional program for hearing-impaired students. These students, as part of their standard curriculum, receive special training in thinking skills, using FIE. To implement this component of the project, the students selected will be distributed into two training groups, one concentrating on FIE instruments which emphasize verbosequential skills, the other on instruments which emphasize the visuospatial (as described below). Before assigning subjects to one of the training groups, all students within the pool of potential subjects will be classified as "Verbosequential" or "Visuospatial", depending on their specialized cognitive performance on the CLB. Members from each Cognitive Profile group will then be assigned by random number to one of the two training groups, so that half the students within each training group will have Cognitive Profiles in which the verbosequential scores are greater than the visuospatial, and half will have the opposite.

In the overall 3-year study, 48 subjects will be selected, including 12 in each of the 4 cells of the 2 x 2 matrix -- involving 2 types of FIE training group (verbosequential or visuospatial) and 2 types of cognitive profile (again, verbosequential or visuospatial). This matrix is charted in Table 1. In the first year of this study, 16 subjects have been trained according to this experimental design -- 4 in each of the 4 cells. Eight (8) of these students have been trained with a concentration on FIE instruments which are verbosequential; 8 with those which are visuospatial. Within each group there are 4 students whose cognitive profiles indicate a greater facility with verbosequential than with visuospatial tasks and 4 whose performance indicates the reverse. Hearing loss, performance IQ, age, and sex distribution are comparable between the training groups, as shown in Table 2.

Table 2. Characteristics of Training-Component Subjects in First Year of 3-Year Cognitive Study

Characteristic	Visuospatial Group (n=8)	Verbosequential Group (n=8)
Composite CLB Scores:		
Verbosequential	-.76	-.80
Visuospatial	-.05	-.10
Cognitive Profile*	.72	.70
Performance IQ (mean)	101.25	101.63
Hearing Loss (PTA in dB)	92.88	92.50
Age (in years)	10.01	22.21
Sex		
Male	2	4
Female	6	4
Handedness		
Right	8	6
Left	0	2
Age of Onset		
Congenital (pre- or perinatal)	3	2
Prelingual but postnatal	4	5
Postlingual (>24 mos.)	1	1
Reading Comprehension (SAT)		
Grade Equivalent (mean)	4.41	4.67

Training Instrument. Feuerstein's Instrumental Enrichment (FIE) program (Feuerstein, 1980) will be used for the training component, because its thinking-skill emphasis is particularly pertinent to the goals of this study. As noted earlier, FIE provides a framework of 14 multi-page paper-and-pencil instruments, each addressing a different cognitive skill. The program is designed to be scheduled over a 2 or 3-year period, with 4 or 5 instruments taught per year. In the Transitional Progam which will be our target group for intervention in this study, only one year is available for instruction, and so modifications in the program schedule are required.

The instruments which will be used with all students in this study, although with specifically varying degrees of coverage, include the following in order of presentation: (1) "Organization of Dots", requiring the subject to identify dot patterns of geomettic shapes to develop organizational skills, systematic search, and ability to identify critical cues; (2) "Orientation in Space", developing perception of self and others in personal space; (3) "Comparisons", identifying similarities and differences among people, objects, words, and events; (4) "Analytic Perception", developing awareness of parts and wholes, analysis, and synthesis; (5) "Instructions", providing directed practice in recognizing, enacting, giving, and following verbal instructions; (6) "Temporal Relations", developing perception of time and orientation to time sequences; (7) "Numerical Progressions", discovering rules that govern and predict successions of events, and build awareness of recurrence in cycles; and (8) "RepresentationalStencil Design," requiring mental reconstruction of models (using mentally superimposed two-dimensional representations of colored stencils), and applying all functions acquired in the preceding instruments. All the instruments are designed in part to bridge between cognitive styles and abilities, but certain of the instruments focus primarily on skills which may be considered either verbosequential or visuospatial. Although we recognize that the

designations are not pure, the instruments to be used in this project have been analyzed for the specialized cognitive functions which they emphasize, and they have been operationally classified as follows: primarily Visuospatial: "Organization of Dots", "Orientation in Space", "Analytic Perception", and "Representational Stencil Design"; primarily Verbosequential: "Instructions", "Temporal Relations", and "Numerical Progressions". One other instrument, "Comparisons", is a composite of both visuospatial and verbosequential skills, and is included in equal portions for both training groups as a necessary step inthe cognitive training program for instructional purposes.

Procedure. All students in the two training groups will receive FIE training 3 days per week, for 1 hour per session throughout the 32 weeks of the Transitional Program year. The same teacher, a certified teacher of the deaf who is fluent in Sign and who has completed the full training program for FIE instruction, will provide the instruction for both groups.

All students will receive instruction in the same 8 instruments, but the amount of instruction will be systematically varied. In "Organization of Dots", for example, an instrument designated as "visuospatial", the Visuospatial group will be given all 27 pages, either in classroom discussion or for homework, while the Verbosequential group will be given only 7 pages. There are 5 major units or levels of complexity introduced in the Organization instrument; both groups will be exposed to all units, in order to preserve the sequence and integrity of the Feuerstein program. The same process will be followed for all instruments, so that in the verbosequential "Instructions", for example, the Visuospatial group will be given only 9 pages (touching on each of the 8 units), compared with all 42 pages for the Verb group. Each group will receive the same number of total pages of cognitive activities, the same

time on task for FIE tasks and will follow the same sequence of training. Only the proportion of verbosequential to visuospatial material will be varied.

Results

Results of the first year of this ongoing project will be reported at the International Symposium in July, 1989. Transparencies and handouts detailing results from both the Evaluation and Training components will be presented at that time.

Evaluation Component

It is anticipated that data from the CLB, as well as from the alternate tests of sequencing and fluency, the tests of hand performance, and the achievement tests will be available and analyzed for 65 hearing-impaired youth and adults, in addition to those evaluated in the previous two studies reported here.

Analysis and Anticipated Results. The central question for this evaluation component is: Do groups of profoundly deaf persons differ from hearing controls: (a) on performance of specialized cognitive functions associated with the brain, and (b) on laterality of brain functions? The dependent performance variables for specialized cognitive function include the individual cognitive tests as well as the verbosequential and visuospatial composites. These variables will be compared to the standard scores of the hearing normative group for each of the hearing-impaired groups by a One-Way ANOVA. Because there are consistent gender differences, separate standard scores are calculated for males and females. The dependent variables for laterality are the indices of laterality as calculated from the time of performance for each hand. Hand differences, group difference, and interactions will be assessed by a Repeated Measures ANOVA. The Index of Laterality will also be used in a One-Way ANOVA. In both the cognitive performance measure and the laterality measure, it is

hypothesized that only the congenitally and profoundly hearing-impaired subjects will show differences from the normally hearing group, and that these differences will be in the same direction as in our preliminary studies -- i.e, with a cognitive profile favoring visuospatial functions associated with the right hemisphere.

The second question is: Do groups differ in specialized cognitive performance and/or in laterality as a function of both age-of-onset and degree-of-hearing-loss? The same dependent performance variables and laterality indices described above will be used in a 2-Way ANOVE with age-of-onset and degree-of-hearing-loss as factors. Reading achievement scores will be used to co-vary for English proficiency. In particular, data are beinganalyzed to determine, as indicated by our preliminary studies, whether: (a) congenitally and profoundly deaf subjects may perform visuospatial skills better than the other onset and severity groups; (b) congenitally and profoundly deaf subjects evidence greater reduction in verbosequential performance than the other groups; and (c) the congenitally deaf group is the least lateralized.

The third question is: What are the specialized cognitive variables that are predictors of academic achievement? Scores on the SAT will be the dependent variables to be predicted in a multiple regression analysis, with the CLB measures of cognitive function as the independent variables. The analysis will be repeated with each subgroup (by age-of-onset and degree-of-loss) to determine if the same factors are involved for each. If the cognitive predictors (CLB scores) for profoundly deaf subjects differ from those with later onset and less severe impairment, these may be clues for remedial training. The Cognitive Profile (difference between visuospatial and verbosequential composite scores) will also be used as a single predictor of achievement.

Training Component

It is anticipated that by July, 1989, data from 16 subjects who have completed the FIE training program, 8 with a Verbosequential focus and 8 with a Visuospatial focus, will be available for analysis and discussion.

Analysis and Anticipated Results. Three major questions will be analyze, based on the Training Component data: (1) Is academic achievement enhanced by remedial training that takes advantage of normal or enhanced visuospatial skills, or contrarily, by training that concentrates on identified deficiencies in sequential processing? (2) Does the subject's cognitive profile influence which training method is most effective? (3) Is there any interaction between training and profile?

A 3-Way ANOVA will be performed, with factors including: (1) pre and post-test SAT scores (repeated measure); (2) profile groups, and (3) training techniques. Across-technique and within-technique analyses will indicate whether training techniques or cognitive profile contribute to group differences. A Training Technique Profile Group interaction analysis will provide insight on how the technique and profile will contribute together to academic improvement; and interactions with the repeated criterion variable (SAT test scores) will suggest whether a profile group, a training technique, or both (in a 3-way interaction) contributes most toward academic improvement. These results will provide the background for our long-term goal of providing the most efficacious training in academic rehabilitation with an eventual view toward earlier intervention.

Glossary

bridging (in Instrumental Enrichment) -- the process of making connections between an immediate task (IE or coursework) and some past, present or future experience.

cogitive asymetry -- performance of tasks by the processes of one cerebral hemisphere compared to performance by the other hemisphere (hemisphericity).

cognitive modifiability -- the concept that thinking skills may be modified through specific cognitive instruction.

cognitive profile -- the pattern of high vs. low performance on abilities for specific (specialized) high-level thinking processes.

commissurotomy -- surgical division of the nerve fiber tracts that connect the left with the right cerebral hemisphere.

critical degree (of deficit) -- the degree of severity in disability in one area (e.g., hearing impairment) beyond which other areas (e.g., cognitive function) are also affected.

critical period -- the cut-off point in early development after which environmental influences are no longer effective for change in the designated skill or process.

hemisphericity -- a type of cognitive profile in which levels of performance on tasks related to the right hemisphere are compared to those related to the left hemisphere.

lateral (-ization, -ity) (of brain function) -- the location, in either the right or left hemisphere of the brain, where specialized brain functions are best performed.

localization (of cognitive function) -- location in the brain of specialized cognitive functions, usually, but not always, referring to the left or right hemisphere.

metacognitive -- instruction which focuses specifically upon the thinking process or "thinking about thinking".

neurosystem -- the system that produces behavior, comprised of the neurotransmitter and nerve connections in the brain.

orthogonal -- a statistical term meaning "not-related".

relative performance -- performance on one set of tasks in relationship to performance on another set of tasks. (The tasks in each set are generally interrelated.)

specialized brain functions -- higher level thinking processes (e.g., speaking, remembering sequences, perception of orientation in space) carried out by specific areas of the brain.

unilateral lesion -- damage in the brain in only one cerebral hemisphere.

verbosequential -- tasks of verbal function (speaking, comprehending language) and of temporal sequencing which are often intercorrelated (usually associated with the left cerebral hemisphere).

visual hemifields -- the left or right viewing area (field) seen, respectively, by the right and left hemi-retina.

visuospatial -- tasks of visual perception of geometric patterns and shapes in space, which are often intercorrelated (usually associated with the right cerebral hemisphere).

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